



METHODOLOGY FOR CALCULATING THE CAPACITY OF AN AUTONOMOUS SOLAR POWER PLANT FOR POWER SUPPLY TO A PRIVATE RESIDENTIAL BUILDING

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Abstract. *The article presents a method for calculating the capacity of an autonomous solar power plant for power supply to a private residential building. The method is based on the analysis of the daily electrical load profile and the sequential determination of the parameters of the main elements of the system: installed capacity, battery capacity, power of photovoltaic modules and an inverter. The work takes into account the starting currents of household electrical receivers, the seasonal duration of the night interval and the coefficients of system losses.*

As a result of calculations, it was found that with a daily energy consumption of $14.99 \text{ kW} \cdot \text{h}$, the maximum load is 6.9 kW , the required battery capacity is about $1450 \text{ A} \cdot \text{h}$ at a voltage of 48 V , and the installed capacity of the photovoltaic array is about 4 kW .

The proposed approach makes it possible to reduce the risk of overestimating the installed capacity of the equipment and ensure economically sound design of an autonomous solar power plant for a private residential building.

Key words: *autonomous solar power plant; power calculation; private residential building; daily load; battery; photovoltaic modules; inverter; autonomous power supply.*

Introduction

In recent years, there has been increasing interest in autonomous solar power plants as a means of ensuring the energy independence of

private residential buildings [1]. This trend is especially typical for regions with high solar activity and unstable centralized power supply [2].

One of the key problems in designing an autonomous solar power plant is the correct determination of its installed capacity [3]. Overestimation of calculated parameters leads to an unjustified increase in capital expenditures, while underestimation of capacity reduces the reliability and stability of the power supply system [4].

A feature of household consumers is the pronounced unevenness of the daily electrical load, the presence of inrush currents of individual electric receivers and seasonal changes in daylight hours [5]. Taking into account these factors requires the use of a reasonable methodology for calculating the capacity of an autonomous solar power plant [6].

The scientific novelty of the work lies in the systematization of the calculated stages of determining the capacity of an autonomous solar power plant, taking into account changes in load over time and seasonal correction of battery parameters.

The purpose of the research

The purpose of this work is to develop and substantiate a methodology for calculating the capacity of an autonomous solar power plant for power supply to a private residential building, taking into account the daily load unevenness and climatic operating conditions.

Statement of the problem

To achieve this goal, we need:

- determine the daily energy consumption of a private residential building;
- set the maximum design load of an autonomous solar power plant;

- calculate the required battery capacity;
- determine the installed capacity of photovoltaic modules;
- justify the choice of inverter power.

Solving the problem

The problem of determining the capacity of an autonomous solar power plant for power supply to a private residential building is solved based on an analysis of the daily load profile and subsequent calculation of the main elements of the system.

The calculation of the daily energy consumption of an autonomous solar power plant is presented in Table. 1.

Table. 1. Daily energy consumption of an autonomous solar power plant for power supply to a private residential building

No	Consumers	Voltage, V Power, (W)	Power on the main bus, W	Working hours/day	Energy consumption W*hour/day
1	Electric kettle	220 V, 2200 W	2500	0,25	625
2	Refrigerator	220 V, 400 W	450	12	5400
3	Кондиционер	220 В, 1000 Вт	1200	6	7200
4	A microwave	220 V, 1500 W	1800	0,25	450
5	TV	220 V, 100 W	100	7	700
6	Indoor lighting (4 rooms), LED lamp	220 V, 45 W	45	8	360
7	Kitchen and shower lighting	12 V, 30 W	30	4	120
8	Other types of consumers (phone charger, vacuum cleaner, etc.)	220 V, 67 W	67	2	134
	Total		6192		14989

The total daily energy consumption is $14.99 \text{ kW} \cdot \text{h}$.

The maximum design load of an autonomous solar power plant is defined as the highest value of the total capacity of simultaneously operating consumers and is 6.19 kW .

The battery capacity is calculated according to the following relationship. The battery capacity of an autonomous solar power plant for power supply to a private residential building is determined based on the value of the night time interval and the permissible depth of discharge [7].

$$C_{\text{AKB}} = \frac{P_{\text{load}} \cdot t_{\text{night}}}{U_{\text{syst}} \cdot DOD}$$

where:

P_{load} – is the average load power during the night period, W ;

t_{night} – is the duration of the night interval, h ;

U_{syst} – is the rated voltage of the system, V ;

DOD – is the allowable depth of discharge (fraction of a unit). In the calculations, the permissible discharge depth of the battery is assumed to be 0.7 (70%).

The average night load is assumed to be 3 kW based on an analysis of the daily consumption profile and the exclusion of daytime energy-intensive devices. Substituting numerical values:

$$C_{\text{Battery}} = \frac{3000 \cdot 16}{48 \cdot 0,7}$$

$$C_{\text{Battery}} = \frac{48000}{33,6} \approx 1429 \text{ A} \cdot \text{h}.$$

Thus, the estimated capacity of the battery is approximately $1400\text{-}1500 \text{ A} \cdot \text{h}$ at a voltage of 48 V .

Determination of the installed capacity of a photovoltaic array: The required installed capacity of the photovoltaic array of an autonomous solar power plant is determined based on daily energy consumption, average duration of sunshine and the coefficient of system losses [8]. At the same time, the efficiency of photovoltaic modules depends on the climatic conditions of operation, in particular, on the ambient temperature and the level of solar radiation [9].

$$P_{PHA} = \frac{E_{daily}}{H_{avarage} \cdot \eta_{syst}}$$

where: E_{daily} – is the daily energy consumption, $kW \cdot h$; $H_{avarage}$ – is the average duration of effective solar generation, h ; η_{syst} – is the loss coefficient of the system (0.8–0.85).

With a daily energy consumption of 14.99 kWh, an average duration of solar generation of 5 hours and a loss coefficient of 0.8, we obtain:

$$P_{PHA} = \frac{14,99}{5 \cdot 0,8}$$

$$P_{PHA} = \frac{14,99}{4} \approx 3,75 \text{ kW}.$$

Thus, the required installed capacity of photovoltaic modules is 3.8–4.0 kW.

Determination of inverter power:

Taking into account the starting currents of the electric receivers and the power reserve coefficient, the inverter must ensure maximum load operation with an additional reserve of 20-30% [10].

$$P_{inv.} = P_{max} \cdot 1,3$$

$$P_{inv.} = 6,19 \cdot 1,3 \approx 8,047 \text{ kW}.$$

Therefore, it is recommended to use an inverter with a rated power of 8-10 kW.

Conclusion

The paper develops a methodology for calculating the capacity of an autonomous solar power plant for power supply to a private residential building, based on the analysis of the daily load profile and taking into account climatic factors.

The calculated parameters of the system are determined: a maximum load of 6.19 kW , a daily energy consumption of 14.99 kW , the required battery capacity of about $1450\text{ A}\cdot\text{h}$ at a voltage of 48 V and the installed power of the photovoltaic array of the order of 4 kW .

The results obtained confirm the effectiveness of the proposed methodology and its applicability in the design of autonomous solar power plants for private residential buildings in regions with high solar activity.

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